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FINAL ENGINEERING REPORT

FOR

EXPERIMENTAL CATHODE RAY TUBES WITH FIBER OPTIC INSERTS IN FACEPLATE

for

NAVY DEPARTMENT BUREAU OF SHIPS ELECTRONICS DIVISIONS
CONTRACT NObrs-87395
CODE 691A1B
PROJECT SERIAL NO. SR008-03-05, TASK 9477

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FINAL ENGINEERING REPORT ON THE 10" CATHODE RAY TUBE WITH FIBER OPTIC INSERT IN THE FACEPLATE

I. INTRODUCTION

This contract calls for the production of two cathode ray tubes with fiber optic inserts in the faceplate. These tubes are to be similar, both mechanically and electrically with the 10KP7A cathode ray tube, except that P-25 phosphor is to be used. The fiber optic insert is to be a 3" x 3" insert located near the outer edge of the useful screen area. The tubes shall be suitable for testing in the AN/L SPA-8A indicator.

Our contract proposal provided for the fiber optic plates to have grey cladding with not more than 20 microns core fibers.

II. CONSTRUCTION TECHNIQUES

The contract provided for a 3" x 3" fiber insert. It is generally known to be bad practice to put in square inserts into glass because of stress concentration and subsequent failure. Permission was requested and approval received to substitute a circular fiber optic piece of 4.25" in diameter in lieu of the 3" x 3" square section presumably called for. Figure 1 illustrates the bulb geometry. It is noted that a full 3" x 3" fiber optic section is still available within the confines of the larger 4.25" diameter circular section.

The grey clad fiber plate production was subcontracted to Mosaic Fabrications, Inc. of Southbridge, Mass. who agreed to supply the fiber pieces using a fiber size of 15 microns with grey cladding.

In order to increase the probability of success in sealing these pieces into the completed cathode ray tube envelope and to speed up the final delivery of the contract, a dual approach toward sealing was used at the Rauland Corporation using our newly acquired glass grinding and polishing facilities and at Mosaic Fabrications, Inc. We carried out a complete series of experiments leading to what would be a completed bulb.

In our own approach, we reached what we feel were completely successful solutions to the various problems in sealing in this rather thick section of unfavorable geometry. We did not do the final sealing with the fiber optic components itself, since by the time our problems were solved, our subcontractor also had made a similar successful approach and was able to supply the bulbs with the fiber optic section inserted.

Our work was all done, therefore, with plain glass inserts. The starting point is Corning Glass 10" cathode ray bulbs as the blank. The front panel section was removed by flame cutting, followed by grinding and polishing both edges so that they could be subsequently rejoined by a fritting technique using a devitrifying type frit. The front panel section was then subjected to a glass cutting operation wherein a circular section of glass about 4" in diameter was removed by using a so-called biscuit type cutter mounted in a drill press with wet abrasives for cutting. The biscuit cutter consists essentially of a brass cylinder mounted to a steel base and attached to a shaft so that it can be inserted and used in a slow speed drill press. The edges of the brass cylinder were slotted to facilitate abrasive action and removal of glass particles. With a little practice it is possible to make successful cuts through the face panel of the cathode ray envelope. Using another panel, a circular disc of approximately 4 1/2" in diameter was cut using a larger biscuit cutter. These two parts were then turned over to the glass grinding shop for grinding and polishing to a close fit. The subsequent edges were given a taper of approximately 8^{o} with the taper being outward.

When using the biscuit type cutter it was extremely difficult to avoid chipping the last part of the glass cut through. Such chips would spoil the panel surface, cause cracks, and act as potential break sources. By careful technique and use of a sealing wax backing, chip free cuts were made. However, where only the panel section was needed and not the glass slug cut out, it is

possible to use another technique. A small pilot hole of say 1/2" was cut through the panel. Then from one side the biscuit cutter cut one half way through, while this was followed by a second cut half way through from the other side, in both cases the pilot hole serving as the guide. Since the cuts meet in the center of the glass, there is little tendency for the glass to chip compared to cutting from one side only.

The glass disc used in this case was a clear dummy and would have been followed by the sealing of a fiber optic component if that were necessary. Considerable difficulty was experienced at first in keeping the two portions in proper alignment and also somewhat in preventing the glass disc from cracking. Proper polishing to remove all crack sources proved successful in eliminating cracking. To facilitate inter-alignment of the disc with the panel, a special jig was made which during the frit operation kept the glass disc in rigid tilt alignment, while providing freedom for the disc to move downward properly as is necessary during the sealing operation. In this way, there was no tipping of the glass disc relative to the panel.

The alignment jig used in holding the face panel in alignment with the insert as made is a "C" clamp type of arrangement. The insert is held by the modified "C" clamp, being clamped both on top and bottom. The "C" clamp was arranged so that it could move freely in a vertical direction only on a vertical shaft. Thus during sealing, the plate was free to drop, but could not tilt. Figure 2 illustrates this type of jig.

It was also found that a good seal could be made even without this jig, if the seal areas were matched very accurately and the plate and panel leveled and weighted so there was no tendency for the plate to tip relative to the panel.

The fritting operation consists of coating the area to be fritted in the panel with a paste made of Kimble devitrifying glass frit #CV-137 and

with 1000 second high viscosity grade nitrocellulose resin dissolved in

amyl acetate. Twelve parts of frit are combined with one part of nitrocellulose vehicle, the portions mixed and extruded onto the seal area in the panel, but not on the disc. This mixture is allowed to thoroughly dry to evaporate the solvents and after proper drying, the glass plate is inserted and the two parts placed in the fritting oven. The two parts are baked up to 425°C where they are kept for one hour and then cooled. For our sealing we use heating and cooling rates of 2 1/2° per minute. However, our experience with fiber optic components is that they must be heated considerably slower as there is considerable internal stress within the plates themselves due to mismatches in thermal expansion of the different components. A polariscope readily shows this. The manufacturer of the fiber components recommend a heating and cooling rate of 1 1/2° per minute and this rate was subsequently used in the successful processing of the finished bulbs by us. After the sealing of the insert into the face panel, the assembly was turned over to the glass grinding shop for grinding and polishing top and bottom contours to make these perfectly flush. The next operation is the resealing of the cone section onto the front panel section containing the insert. This is another fritting operation somewhat similar to that described above, except that this butt type seal is rather easy to frit. To assure proper alignment between the cone and face panel, which alignment is rather critical to avoid implosion in the completed tube, a jig was built to hold these in alignment during the sealing operation.

The frit composition and bake temperatures and cycle were identical to that of the first frit. Figure 3 illustrates a completed cathode ray bulb as made in our laboratory with a clear insert of the proper size in the face and the face subsequently sealed to a funnel.

Figures 4 and 5 are photos of the cathode ray envelopes with fiber optic inserts as supplied by Mosaic Fabrications. The approach used by Mosaic Fabrications was similar to that of our own, namely separating the

funnel from the faceplate, inserting the fiber optic section by means of the devitrifying frit and subsequently fritting on the cone section in a second fritting operation. A minor difference is that a Corning devitrifying frit was used instead of the Kimble devitrifying frit we used. The Corning frit number is #89 and is the equivalent of Kimble frit CV-127, both of which are recommended for sealing glasses of the same expansion characteristics as the cathode ray bulb envelope (G-12 glass).

III. THE FIBER OPTIC PROPERTIES AND CHARACTERISTICS OF THE BULB

a) FIBER OPTIC PROPERTIES

The fiber optic insert plate which is 4.250" in diameter is composed entirely of fibers with no clear surrounding area used. The numerical aperture of the fibers is .66 and fiber size is 15 microns. Lead glass is used in the fiber core. The fibers are of the grey cladded type and there is no overlay or overcoat on the fiber surface.

b) BULB CHARACTERISTICS

Fiber optic plates supplied to this Company for other purposes, even though of much smaller size have shown considerable stress when viewed through the polariscope. We, therefore, had the completed bulbs subjected to a polariscopic examination and a rather high stress of the tension variety running from 800 to 1300# per square inch tension was found, with the average being over 1000# P.S.I. These plates were subjected to a vacuum leak test using a Consolidated Engineering Corporation leak detector and no leaks could be located within the limits of the leak detector, Model 24-101A, of the helium mass spectrometer type. A calibration of the leak detector indicated that if there is a leak it would be less than 3×10^{-8} cc/sec. at STP. The completed bulbs were also tested for stress while under vacuum and as expected higher tension values were found running up to 1500# P.S.I. at spots.

IV. SCREENING

Following leak testing, processing and polariscope examination of the bulbs, they were turned over for screening with P-25 phosphor. Before screening these actual bulbs, considerable work was done on duplicate bulbs of the same variety in order to develop a screening formula which could be readily removed if found necessary. It was recognized that the presence of lead glass would render the fiber optic insert extremely sensitive to the acid cleaning operation used prior to screening. Lead glasses are notoriously soluble in hydrofluoric acid used for cleaning. It was considered important to develop modified screen formulae since it is usually necessary in making good cathode ray high quality good resolution screens to rescreen several times. Some work was done toward using a detergent cleaning method in lieu of hydrofluoric acid, but this was not carried out to a successful conclusion since there was an indication of a stain left during subsequent bake where traces of the detergent remained. It is, however, believed that with more work detergent cleaning can be successful. We proceeded with the screening using hydrofluoric acid cleaning of a more dilute variety for a shorter period of time than usual. For screening we used the liquid sedimentation method with barium nitrate and potassium silicate as coagulating medium in deionized water.

For filming, we first tried nitrocellulose flotation, but could not get sufficient adherence of the film so that it would not lift off with the "soft" screening formulas we were using. We, therefore, changed to a conventional spray filming procedure using methacrylate resins dissolved in toluene and a new "harder" screening formula. Following filming, the bulbs were aluminized with 90 milligrams of aluminum at a distance of 9".

V. BULB BAKE AND EXHAUST

Following aluminizing and dagging, the bulbs were then baked at a peak temperature of 380°C for twenty minutes using the slow heating and cooling rates of 1 1/2°C per minute. Following the bake out of the completed screen

bulbs, high resolution guns were sealed in with a lathe in a conventional manner and the entire assembly was then put through the exhaust cycle. For exhaust, a bake temperature of 360°C was used with the slow heating and cooling rates given previously. The bake cycles and exhaust cycles of the bulbs proved successful despite the high internal stress of the fiber insert. No bulb was lost in either of these operations.

VI. COMPLETED TUBES

Two tubes were completed from the two bulbs manufactured. The first was inspected and accepted by the Navy Inspector and has been shipped. The second bulb has been inspected by the Navy Inspector and no final decision has as yet been made concerning its acceptability. In this bulb there is an etch pattern in the fiber optic section due to rescreenings found necessary. There is no specification covering this etch pattern and we can not know if this would in any way detract from the usefulness of the bulb. We, therefore, requested and received permission to ship this tube on a conditional basis, subject to inspection or rejection by the facility using this tube, as the local Navy Inspector was completely unfamiliar with the use to which it was to be put and could not determine whether this difficulty would render this tube unuseable.

VII. GENERAL

The tube already shipped meets all requirements of the contract. The phosphor screen used therein was tested in a duplicate bulb for brightness and decay characteristics and found satisfactory; electrical and mechanical characteristics were all met and in particular the resolution of the tube exceeds that of the contract requirements. The special high resolution guns were made and tested in duplicate tubes so that the resolution requirements of this tube could be met with confidence. Phosphor brightness and decay characteristics were also measured in duplicate tubes and found satisfactory. The vacuum in the tube shipped was excellent, the gas ratio being .005. Line width "A" at 200 microamperes, DC was 0.313 millimeters and line width "C" was a .43 millimeter. The

requirements called for .38 millimeters and .55 millimeters respectively.

The completed tube is shown in Figure 6 and again in Figure 7 with rasters thereon, the full tube face and raster being shown in Figure 6 and an enlargement of the fiber area and surround is shown also with a raster similarly enlarged in Figure 7. Only one of the areas is in optimum focus since the fiber optic area produces an image on the outside surface, while the other areas have the image on the inside surface and both can not be in optimum focus simultaneously.

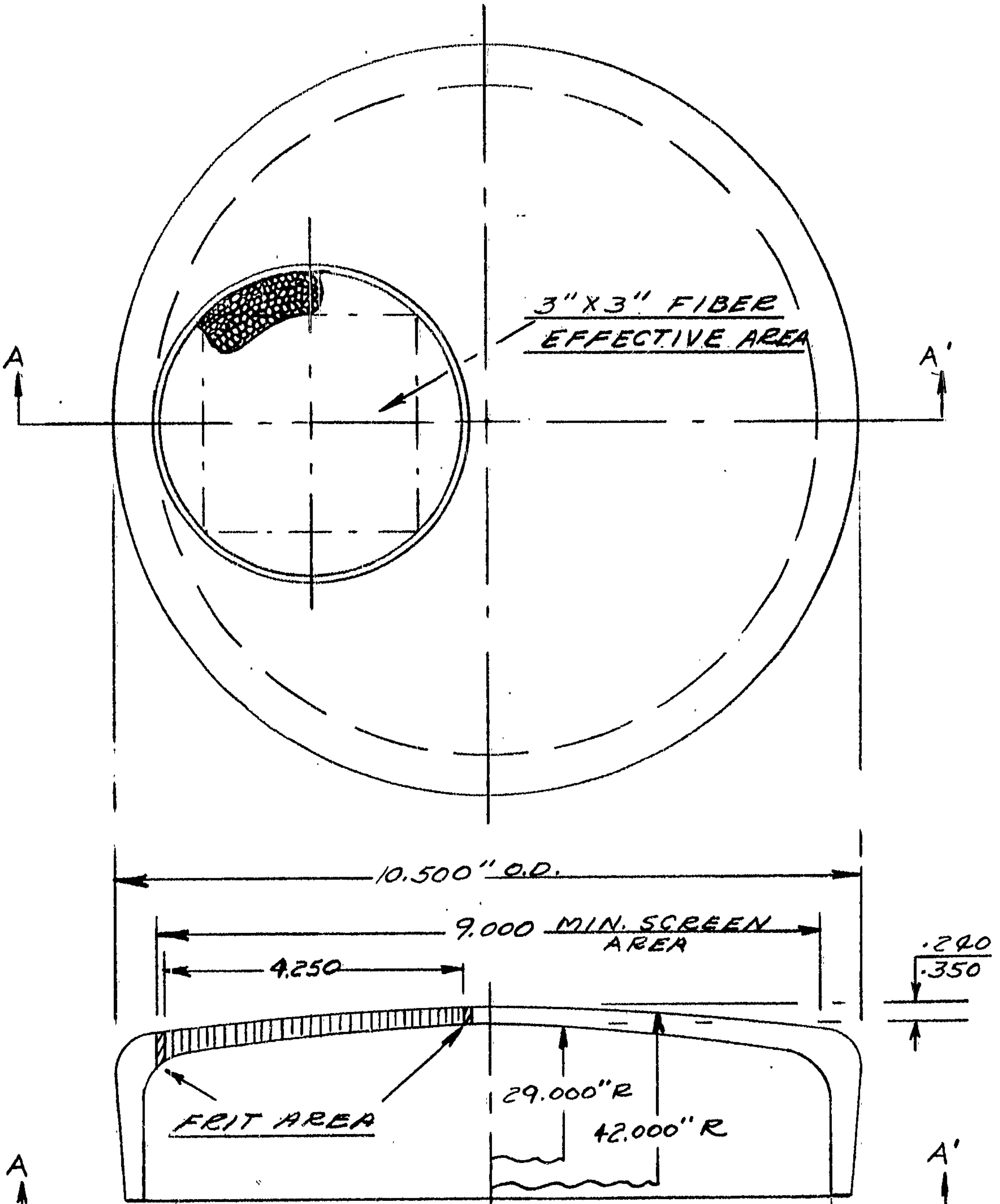
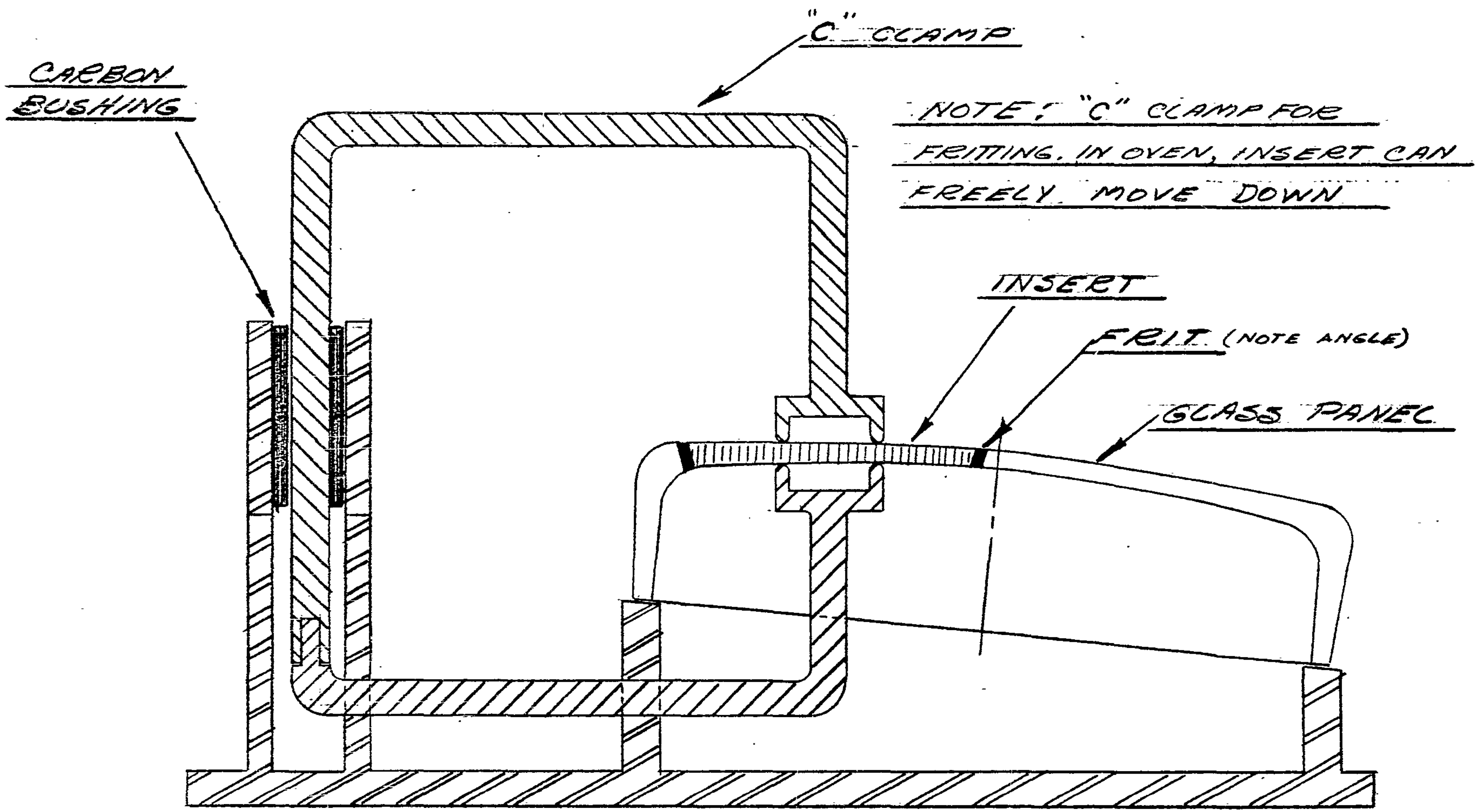


FIG. 1 10" C.R.T. WITH FIBER OPTIC INSERT



"C" CLAMP FRITTING FIXTURE
FIGURE-2

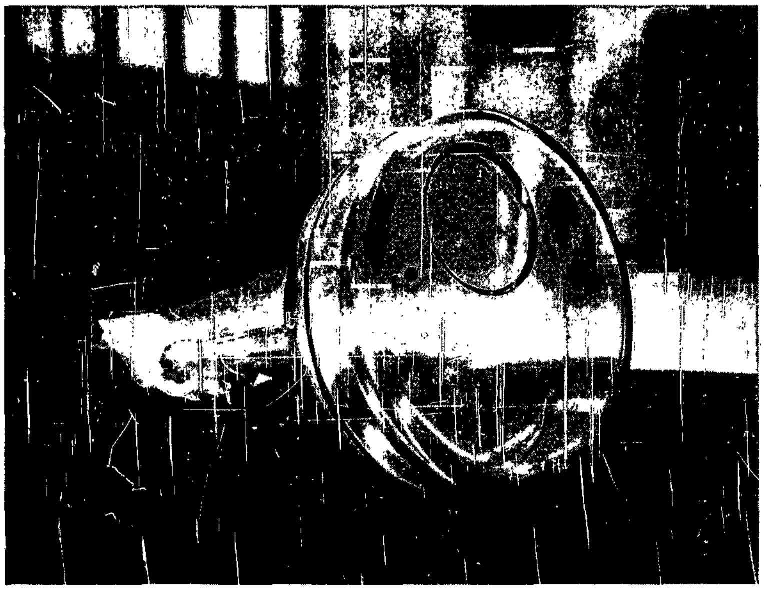


FIGURE 3

FIGURE 4

FIGURE 5

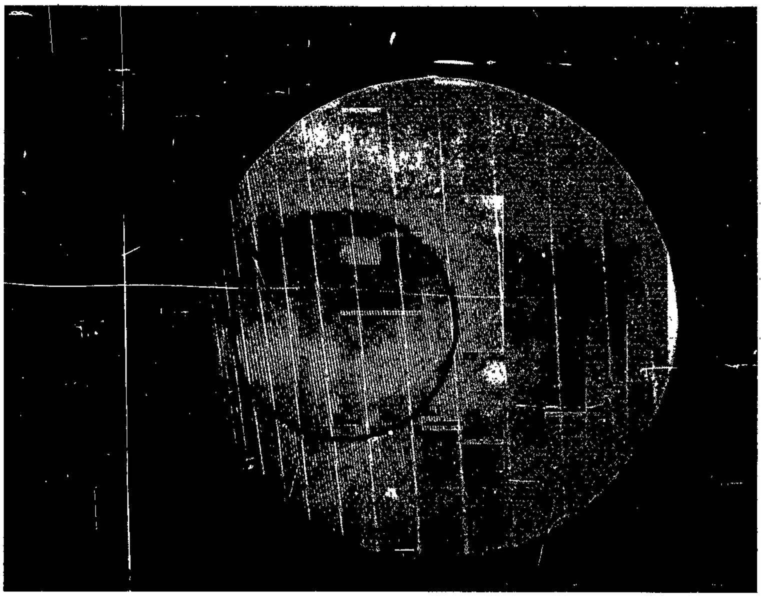


FIGURE 6

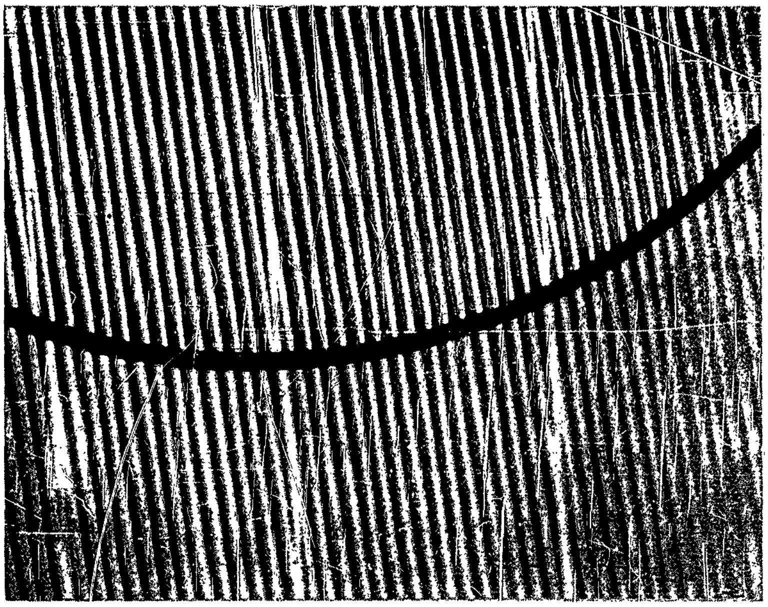


FIGURE 7